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Bergman [45] Jan. 4, 1983

[54] SYSTEM FOR STABILIZING A FLOATING VESSEL

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[21] Appl. No.: 216,485

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Related U.S. Application Data

[60] Division of Ser. No. 28,059, Apr. 9, 1979, Pat. No. 4,261,277, which is a continuation of Ser. No. 831,894, Sep. 9, 1977, abandoned, which is a continuation-in-part of Ser. No. 787,756, Apr. 15, 1977, Pat. No. 4,140,074.

[51] Int. Cl.³ B63B 39/00
[52] U.S. Cl. 114/125
[58] Field of Search 114/121, 123, 125, 265, 114/122

[56] **References Cited**

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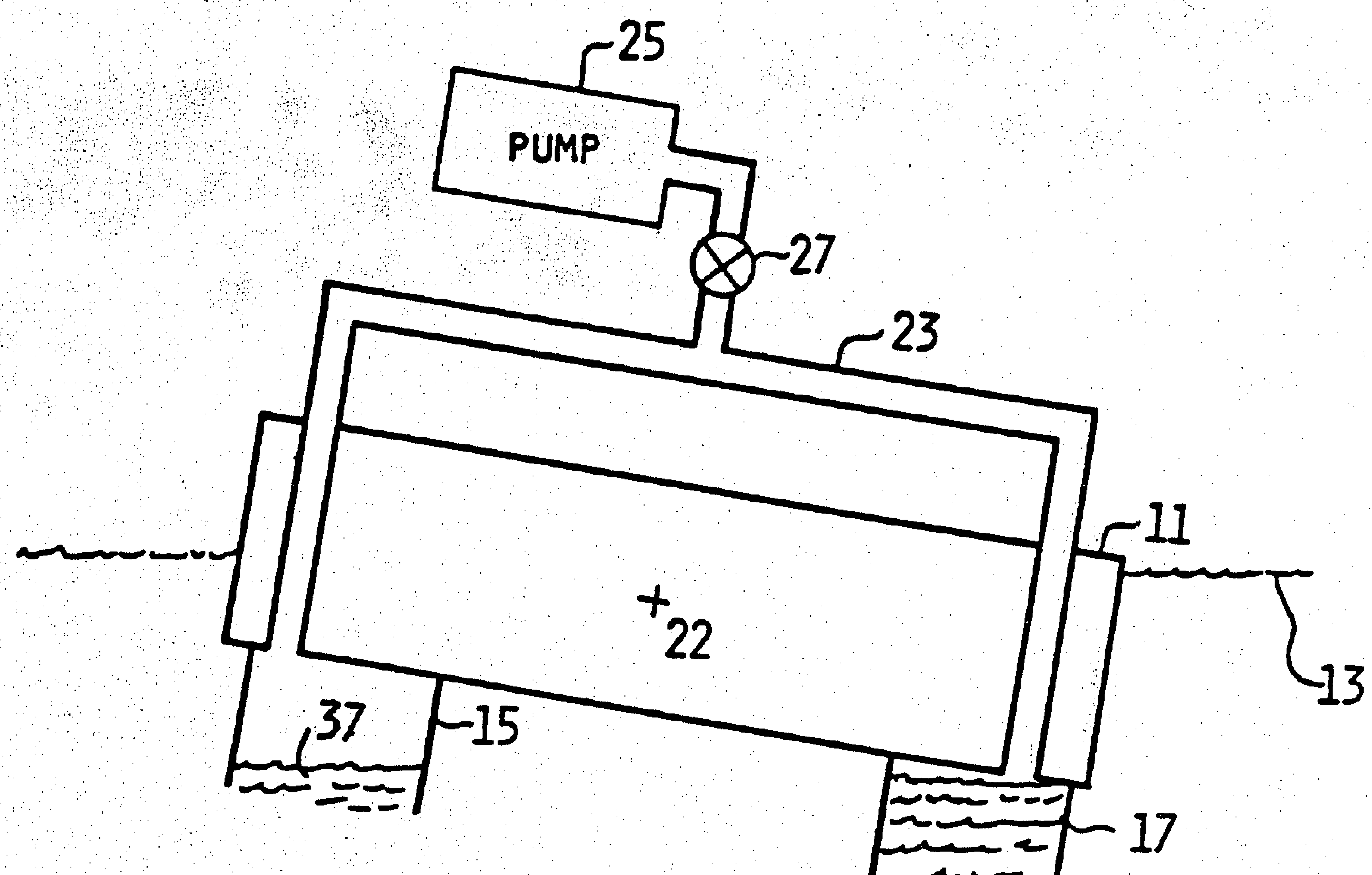
[57] **ABSTRACT**

A seagoing vessel is stabilized by a passive system including tanks symmetrically disposed on the vessel below the water line. The tanks are connected by a conduit and pressurized with air to a selected pressure level. During each oscillatory roll and/or pitch cycle of the vessel, the tanks alternately fill and drain with selected volumes of water to reduce the righting moment of the vessel. The period of oscillation of the vessel is thus lengthened beyond the period of wave motion.

2 Claims, 8 Drawing Figures



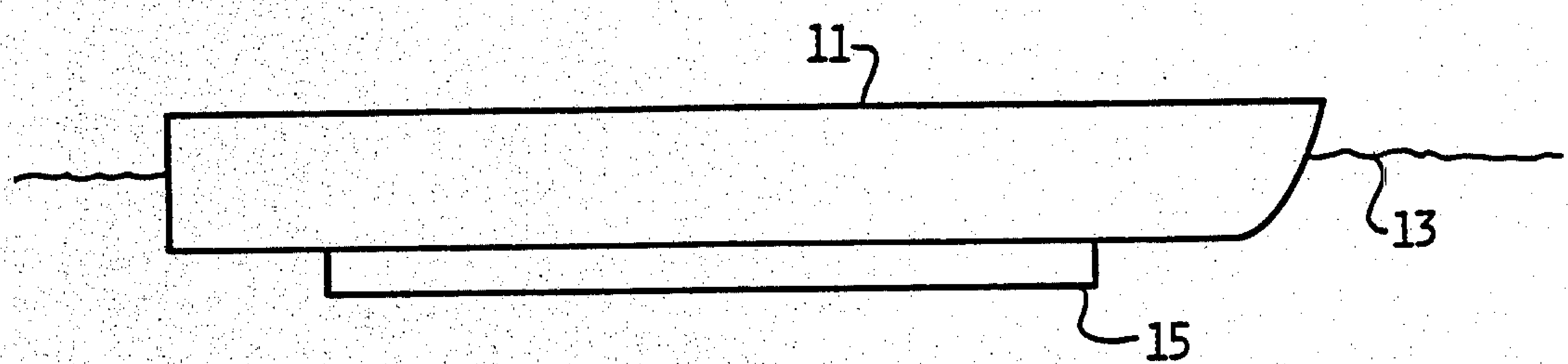


Figure 1

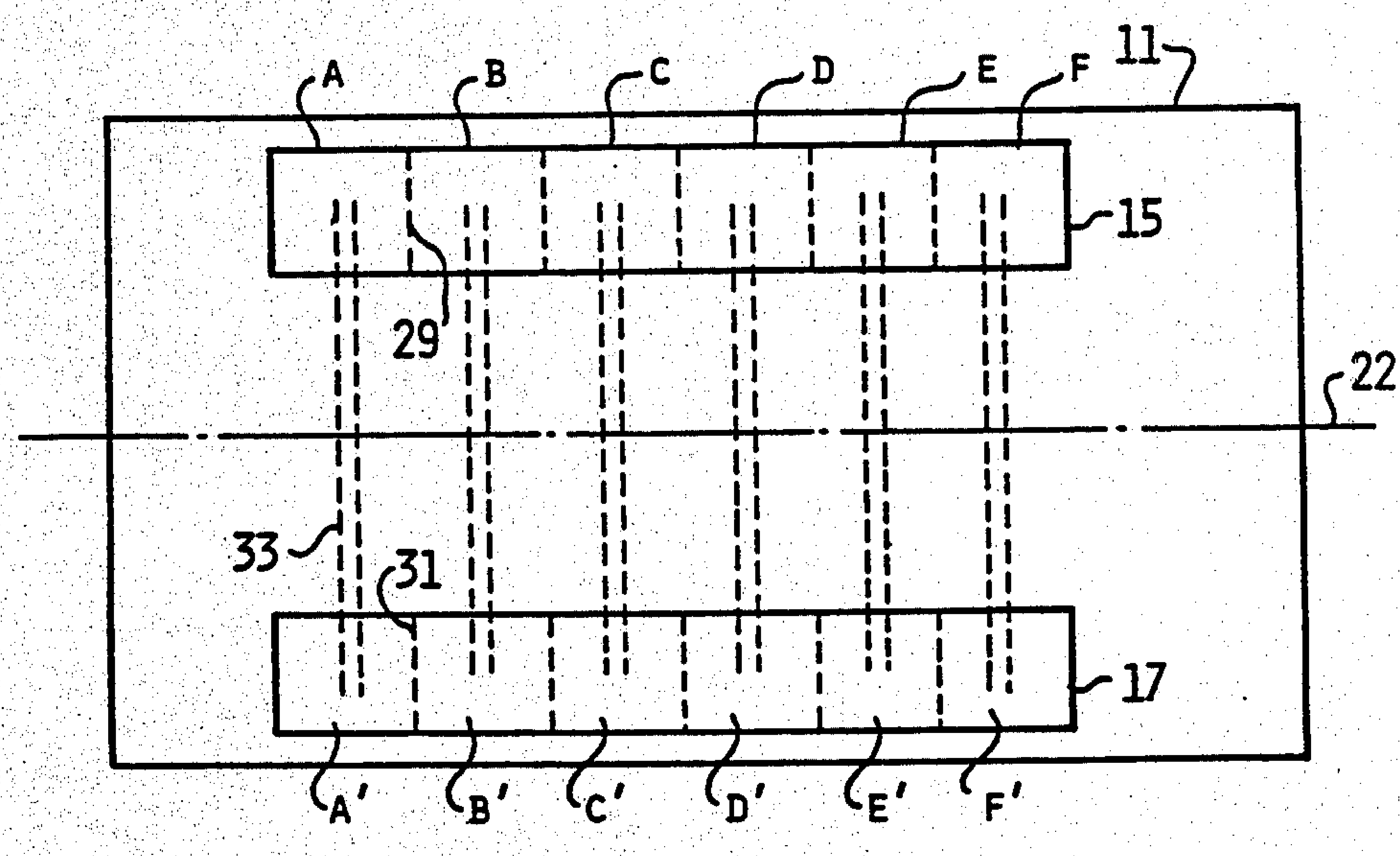


Figure 2

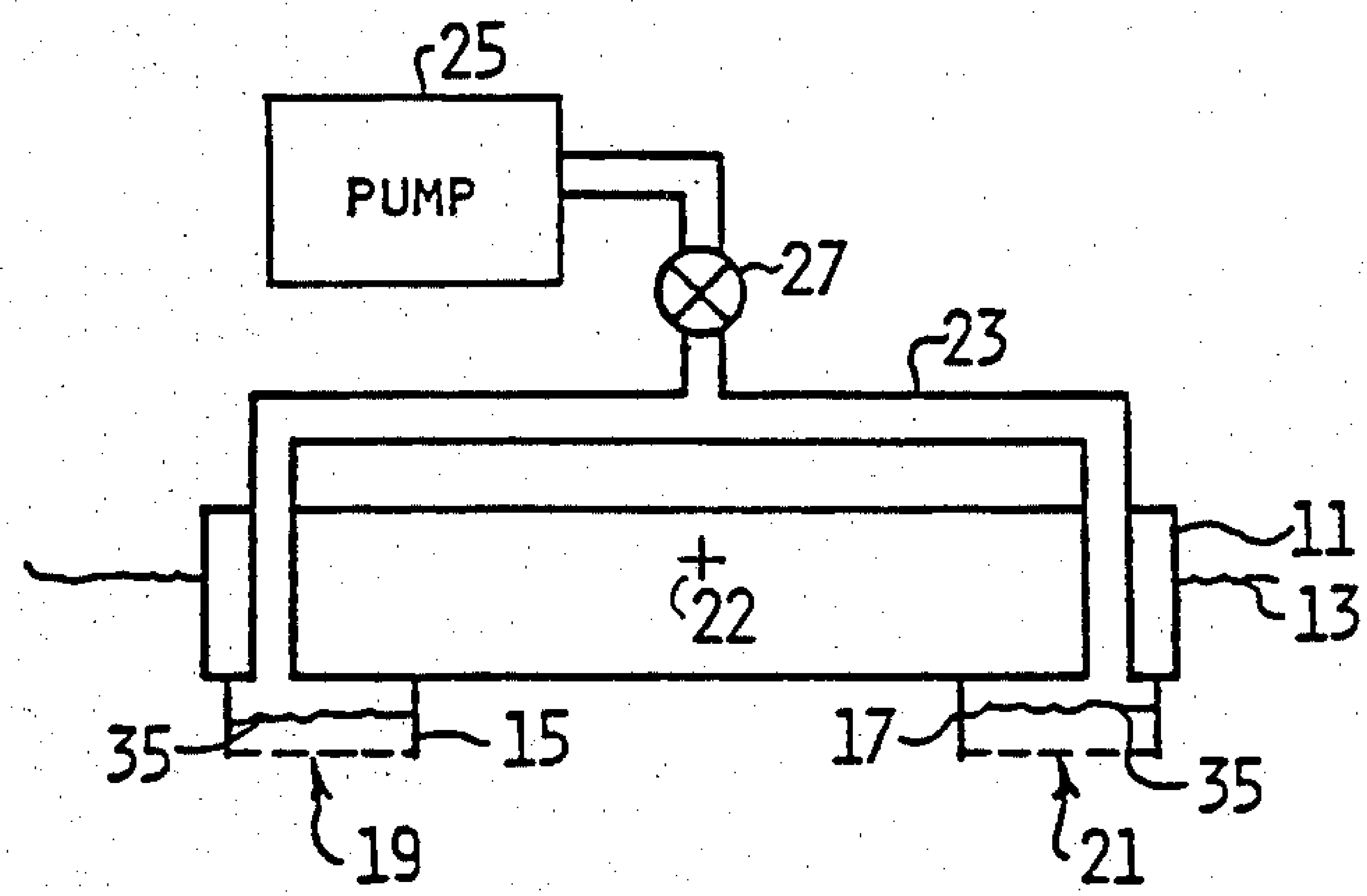


Figure 3A

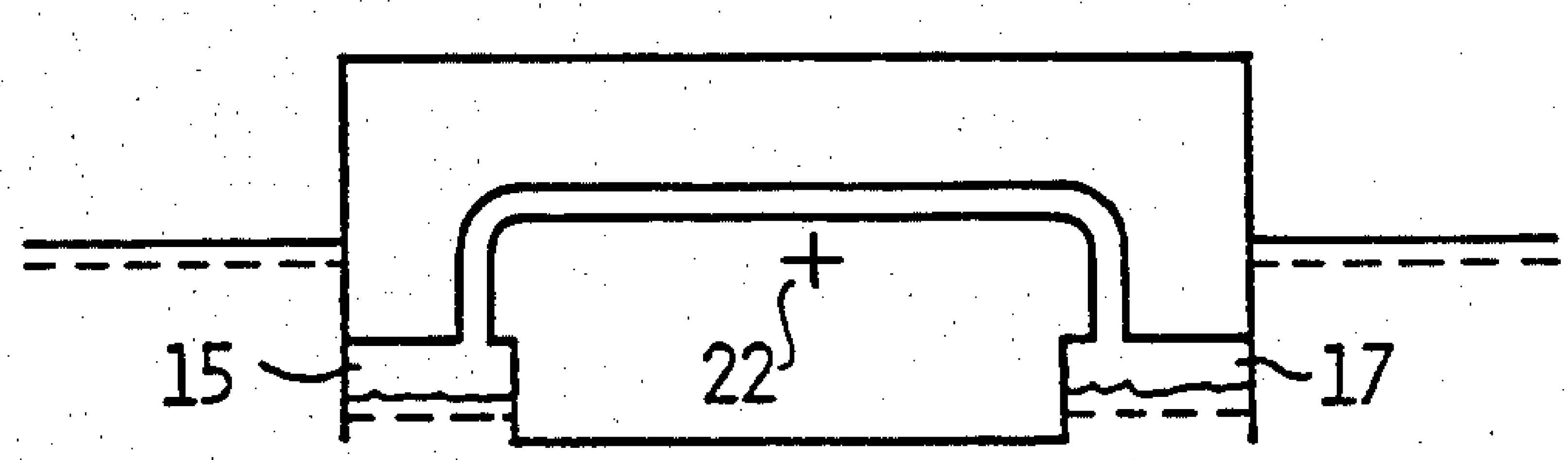


Figure 3B

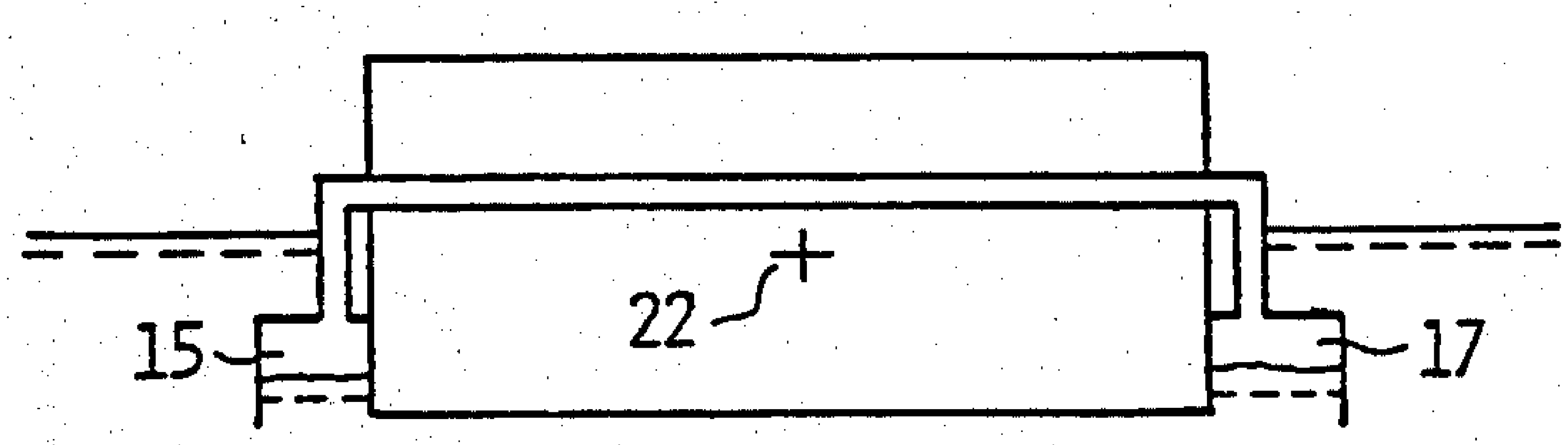


Figure 3C

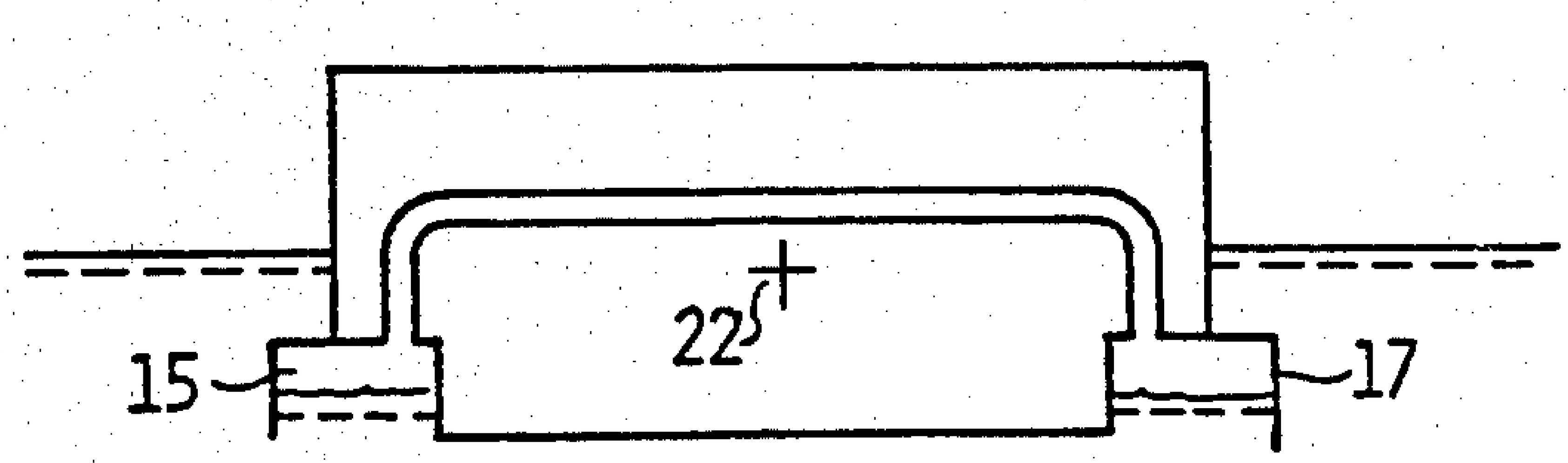


Figure 3D

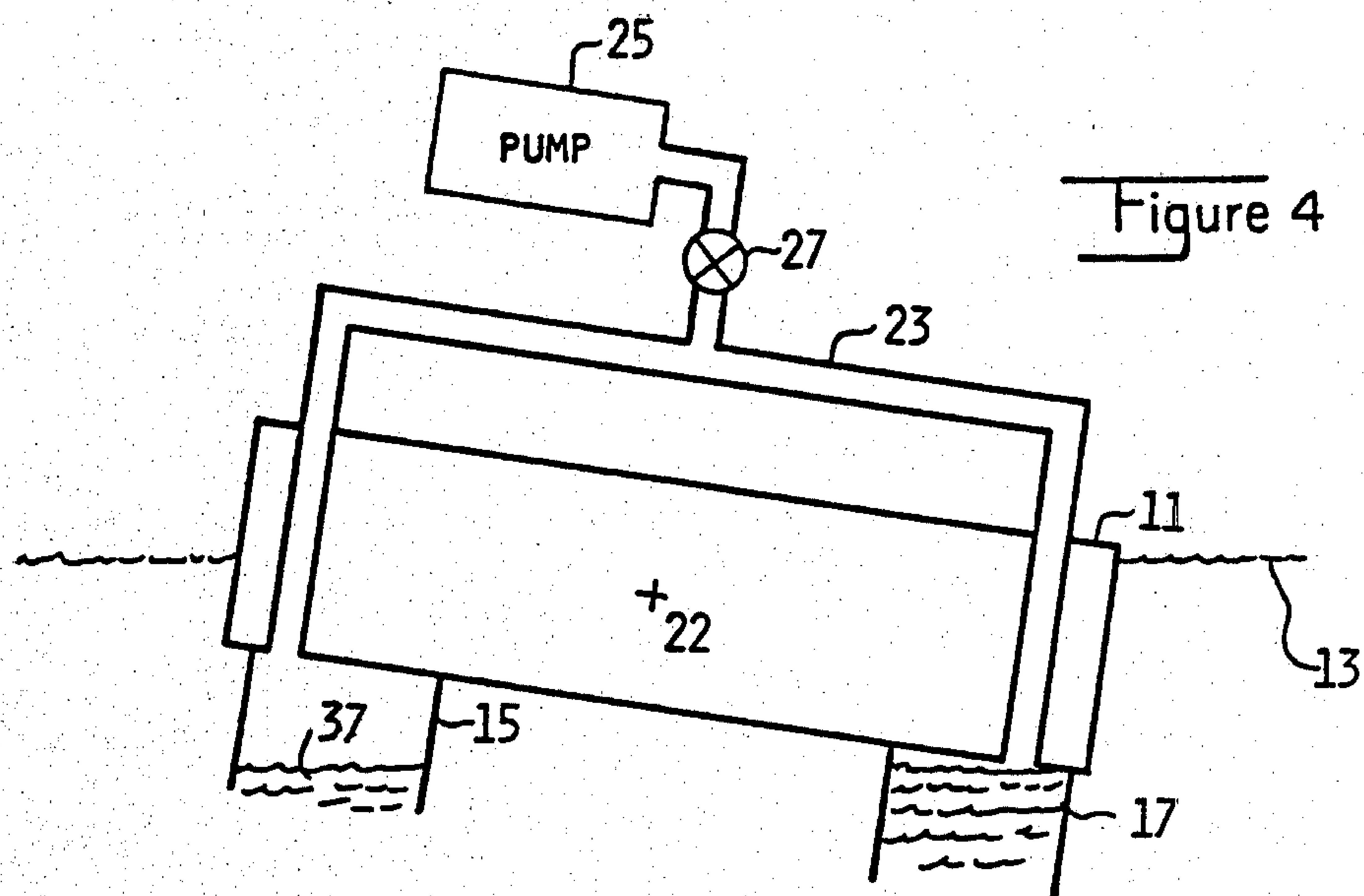


Figure 4

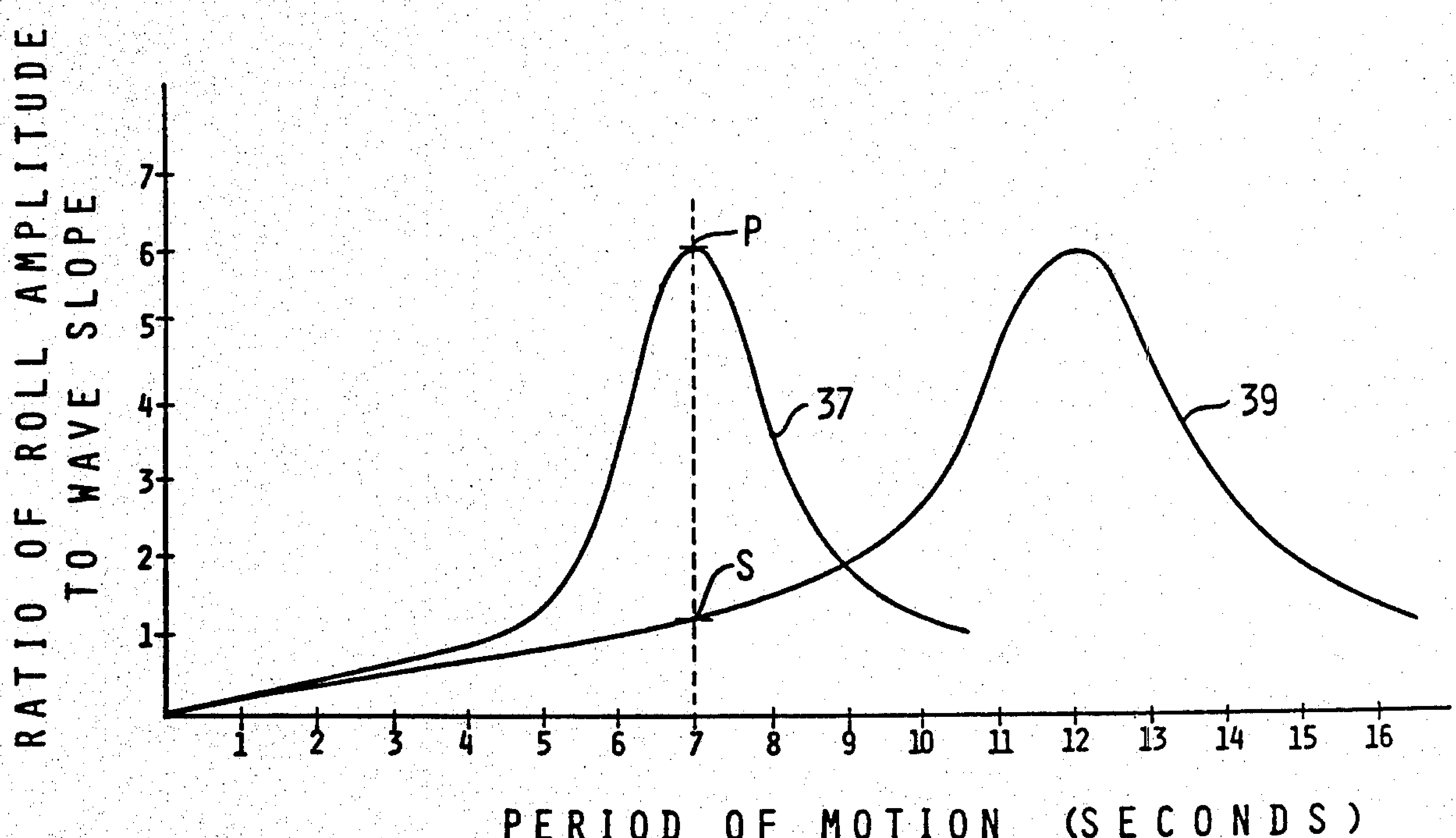


Figure 5

SYSTEM FOR STABILIZING A FLOATING VESSEL

CROSS REFERENCE TO RELATED APPLICATION

This is a divisional of the application entitled, "System for Stabilizing a Floating Vessel", Ser. No. 028,059, filed by Gunnar B. Bergman on Apr. 9, 1979, now U.S. Pat. No. 4,261,277, which was a continuation of the application entitled, "System for Stabilizing a Floating Vessel", Ser. No. 831,894, filed by Gunnar B. Bergman on Sept. 9, 1977, which was a continuation-in-part of the application entitled, "System for Stabilizing a Floating Vessel", Ser. No. 787,756, filed by Gunnar B. Bergman on Apr. 15, 1977, now U.S. Pat. No. 4,140,074.

BACKGROUND OF THE INVENTION

Seagoing vessels are required in various types of offshore operations, including scientific surveys and oil and gas drilling and production. Such vessels are typically configured as drillships, barges and jack-up rigs, as well as supply and service ships.

Both active and passive techniques have been proposed for damping the natural oscillatory displacement of vessels to achieve roll and pitch stabilization in seas having periodic wave motion. Such techniques have utilized water tanks on the vessels and various arrangements of blowers, pumps, valves, valve actuators, roll and pitch sensors, and electronic control circuits for moving water in the tanks to counteract oscillatory roll and pitch motion. A common objective of heretofore known systems has been to make the natural frequency of oscillatory flow of water in the tanks approximately the same as the natural frequency of oscillations of the vessel, thereby to "tune" the tanks to the vessel. Once tuned, the damping action is achieved by causing the flow pattern of water in the tanks to be approximately 90° out of phase with the natural oscillations of the vessel. The forces produced by the water in the tanks then tend to counteract the roll and pitch forces on the vessel.

Prior systems that attempt to achieve stabilization in the manner described above have the disadvantage that large counteracting, damping forces must be produced in order for the system to be effective. The equipment required to provide the large counteracting forces is complex and expensive. In active systems, high power blowers and pumps are typically required. Passive systems generally require high-capacity valves, special stabilizing tank configurations and control circuits for timing the flow of water in the tanks.

SUMMARY OF THE INVENTION

The present invention provides stabilization of a seagoing vessel with a passive system which does not rely on the use of tanks having a natural period which is substantially the same as the natural oscillatory period of the vessel to produce large counteracting forces that damp the angular motion of the vessel. Instead, tanks are used for the purpose of reducing the righting moment of the vessel as described below.

In accordance with illustrated embodiments of the invention, water tanks are disposed on opposite sides of the longitudinal axis of symmetry of the vessel. The tanks are located below the water line, preferably on or near the bottom of the hull of the vessel. The tanks have a shallow configuration, with larger horizontal dimensions than vertical dimensions. The bottom portion of each tank is substantially open to the sea to permit sea water to rapidly fill and drain from the tanks in short time periods which are generally much shorter than the period of natural oscillatory motion of the vessel. An open conduit interconnects the tanks to provide a continuous air passageway between them. An air pump is coupled to the conduit to presurize the tanks to a preselected pressure level for selectably controlling the water levels in the tanks during oscillatory wave motion.

In operation, the water tanks alternately fill and drain in synchronism with oscillatory wave motion. For example, as the vessel tends to roll clockwise on its central longitudinal axis, the tank on the right side of the vessel will quickly fill through its large bottom opening. Air is forced out of this tank through the conduit and into the tank on the left side of the vessel. The increased air volume in the left tank rapidly forces water out of it. As the vessel tends to roll counterclockwise, the left tank fills and the right tank is forced to drain under the force of the air pressure in the system.

The present invention acts to reduce the righting moment of the vessel in a periodic sea. For example, as the vessel tends to roll in one direction, the system reduces the tendency of the vessel to restore itself to an upright position. The reduction of the righting moment lengthens the period of oscillation of the vessel beyond the wave period of the sea. This in turn substantially reduces the amplitude of the roll.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view of a vessel illustrating one embodiment of the stabilizing tanks of the system constructed according to the principles of the present invention.

FIG. **2** is a bottom view of the vessel of FIG. **1** illustrating the location and coupling of the stabilizing tanks.

FIGS. **3A–3D** are diagrammatic end views of the vessel of FIG. **1** illustrating alternative embodiments of the stabilizing system constructed according to the principles of the present invention.

FIG. **4** is a diagrammatic end view of the vessel of FIG. **1** illustrating the operation of one embodiment of the system of the present invention.

FIG. **5** is a graph illustrating the magnitude of the ratio of roll amplitude to wave slope as a function of the period of wave motion for vessels with and without the system of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGS. **1** and **2**, there is shown a vessel **11** in the form of a barge of the type used in offshore oil drilling operations. Disposed below the water line **13**, on the bottom of barge **11** are two elongated tanks **15**, **17**. Tanks **15**, **17** respectively, have bottom portions generally designated at **19**, **21** (FIG. **3A**). Bottom portions **19**, **21** are preferably substantially open to the sea; however, alternatively the bottom portions may be covered by a perforated plate or grating to provide greater structural strength. The tanks **15**, **17** each have a shallow configuration, with larger horizontal dimensions than vertical dimensions. With this arrangement, sea water may fill and drain from the tanks very rapidly. More particularly, the tanks must be configured so as to permit filling and draining during time periods which are much shorter than the time required for the barge to complete one cycle of natural oscillatory roll or pitch motion in a periodic sea.

With reference to FIG. 2, barge **11** has a longitudinal axis of symmetry **22**. Tanks **15, 17** are diposed symmetrically in spaced-apart relation on opposite sides of axis **22**. Each of the tanks **15, 17** may be divided into a plurality of separate compartments. Tank **15** comprises six compartments A, B, C, D, E and F, each isolated from the other by intermediate walls represented by dashed lines **29**. Similarly tank **17** comprises separate compartments A', B', C', D', E' and F' isolated by walls **31**. The compartments are disposed in spaced-apart symmetrical pairs on opposite sides of longitudinal axis **22**, the pairs comprising compartments A and A', B and B', etc. Compartmentalization of tanks **15, 17** serves to minimize excitation of waves and undesirable consequent wave forces on the free water surface contained inside the tanks.

Each pair of compartments is coupled by separate conduit means, generally indicated by dashed outline pipes **33**. Thus, the pair of compartments A, A' is coupled in a closed pressurized system as shown in FIG. 2. The other pairs of compartments are similarly separately coupled. A common blower and ducting arrangement (not shown) may be used to supply air pressure to all pairs of compartments.

Tanks **15, 17** are coupled together by a conduit **23** shown diagrammatically in FIG. 3. Conduit **23** is in the form of a continuous, open pipe providing an air passageway between the tanks. One end of conduit **23** is connected through a port to the top surface of tank **15**, while the other end of conduit **23** is connected through a port to the top surface of tank **17**.

Means including an air pump of blower **25** and air valve **27** are coupled to conduit **23** to provide air pressure in the conduit and tanks **15, 17**. Conduit **23** and tanks **15, 17** form a closed system and the air pressure therein may be selected by opening valve **27** and operating pump **25** until a desired air pressure is reached. Thereafter, valve **27** is closed. Alternatively, valve **27** may be eliminated or left open and air pump **25** continuously operated at a selected rate to maintain the desired air pressure in the system. Preferably the air pressure is adjusted until sea water is permitted to fill the tanks alternately during oscillatory wave motion, as hereinafter described.

The desired reduction of the righting moment when the vessel is caused to heel is a consequence of sea water entering a tank on one side of the vessel and leaving a tank on the opposite side of the vessel in approximately equal quantities as a result of the existence of an open connecting air-filled duct. Thus, the location and configurations of tanks **15** and **17** may be varied as shown in FIGS. 3B, 3C and 3D (pump **25** and valve **27** not shown). FIG. 3B shows the tanks on the bottom but within the hull of the vessel. This arrangement may be preferred for incorporating into new vessels during construction. FIG. 3C shows tanks **15** and **17** outside and at the sides of the hull, at or near the bottom. This, as well as the configuration of FIG. 3A may be preferred for retrofitting existing vessels since the integrity of the original hull is left essentially unchanged. FIG. 3D shows still another embodiment wherein tanks **15** and **17** are partially inside and partially outside the hull of the vessel, at or near the bottom.

All four configurations are based on the same generic principle that, as the vessel is caused to heel, water enters the tank on the depressed side and departs from the tank on the opposite elevated side. This shift of the ballast water volumes in the tanks leads to a heeling torque acting in the same direction as the applied torque. The required applied torque for a given heeling angle is therefore reduced. The restoring torque is in other words reduced, and the natural period of roll lengthened.

Operation of the system of FIGS. **1–3D** may be understood by reference to FIGS. 3A and **4**. As shown in FIG. 3A, the tanks **15, 17** of vessel **11** are initially pressurized by air pump **25** so that sea water fills about one-half of each tank in a quiet sea, as indicated by the water surfaces **35**. As vessel **11** tends to roll about axis **22** in a clockwise direction, as shown in FIG. **4**, tank **17** will fill with water, thus driving air out of tank **17** through conduit **23** and into tank **15**. The increasing volume of air in tank **15** forces water to drain from the tank and lowers the level of water surface **35** to a new level **37**. During this operation, either valve **27** is closed, or valve **27** is open and pump **25** is running to maintain constant air pressure in the tanks and conduit. Thus, the volume of air displaced from tank **17** is transferred to tank **15**. When roll displacement is counterclockwise, tank **15** is filled and tank **17** is drained in the same manner as described above.

The filling of tank **17** with water as the vessel **11** tends to roll clockwise has the effect of reducing the righting moment of the vessel. In other words, the tendency of the vessel to return to an upright condition after a roll is commenced will be reduced, thus making the oscillatory roll motion of the vessel more sluggish. The roll period of the vessel is lengthened. In a typical sea where the wave motion has a seven second period, the roll period of the vessel produced by the system of the present invention is preferably lengthened to about twelve seconds. Since the roll period of the vessel is substantially longer than the period of wave motion, the waves have a greatly diminished effect on the vessel.

The reduction in righting moment of the vessel in a quiet sea by the system of the present invention will also reduce roll torque in a sea having periodic wave motion. Tanks **15, 17** are dimensioned such that when air has been pumped into them, there is still a positive metacentric height, i.e., a positive righting moment. During operation in a periodic sea, there may be a tendency for the vessel **11** to overturn if the righting moment is reduced too much. This is especially true if the vessel is subjected to strong winds. A significant safety feature of the system of the present invention is that the tank height dimension and initial quiescent water level within the tank (e.g., tank **17**) are selected so that, during a very large roll of the vessel, the tank fills completely. Once the tank is filled, the normal buoyancy forces on the vessel are restored and the righting moment increases rapidly as a function of additional angular roll displacement which prevents capsizing of the vessel.

For the tank configuration shown in FIGS. 3C and 3D the open-bottom tanks are external underwater sponsons. The tanks are pressurized by air, vessel rolling or the incidence of a wave causes the water in the tanks to rise and fall, the restoring torque (i.e., righting moment) is reduced and the natural period of roll lengthened, as described earlier in this specification. In these cases, however, torques arising from wave-induced forces on the wetted tanks topside oppose the torques generated by wave forces on the hull itself. The net result is a reduction of the total wave-induced torques on the vessel just as for the internal tank configuration.

FIG. 5 illustrates by comparison the effect of a reduced righting moment on vessel 11 produced by the system of the present invention. Curve 37 shows the ratio of roll amplitude to wave slope for a vessel which is not stabilized; whereas curve 39 illustrates the roll amplitude characteristic for vessel 11 stabilized according to the principles of the invention. The unstabilized vessel has a roll amplitude characteristic with a resonant peak at seven seconds. Wave motion in an open sea also typically has a seven second period. Thus, without stabilization the vessel will have a roll amplitude which is at or near the maximum point P of its resonant peak. In contrast, the stabilized vessel 11 has a resonant peak which occurs at about a twelve second period, which is substantially longer than the typical seven second wave period in an open sea. Thus, for seven second waves, the stabilized vessel will operate at point S on curve 39, and the roll amplitude will be reduced to less than one-sixth of what it was in the unstabilized vessel.

Vessel 11 is a barge about 375 feet long. Each of the tanks 15, 17 is about 275 feet long and divided into several compartments of equal size. The width of each tank is 10 to 12 feet and its height is 6 to 7 feet. The conduits 23 which connect the compartments of the tanks are each about 3 to 4 feet in diameter.

Although vessel 11 is shown as a barge, other types of vessels may be stabilized utilizing the principles of the present invention. For example, the stabilization system may be applied to triangular or rectangular shaped jack-up oil drilling rigs. The tanks may be symmetrically disposed with respect to the geometric center of the vessel, e.g., at the vertices of a triangular shaped rig or at the corners of a rectangular rig. In order to stabilize against both roll and pitch, all tanks may be coupled in common through conduits to a source of air pressure. With this arrangement both roll and pitch righting moments are reduced.

I claim:

1. A passive method for stabilizing a seagoing vessel during repetitive cycles of oscillatory motion by reducing the righting moment of said vessel and lengthening the period of oscillation of said vessel beyond the wave period of the sea, said vessel having at least two tanks disposed on opposite sides of an axis of symmetry of said vessel below the water line, the method comprising the steps of:

interconnecting said two tanks with conduit means to provide a continuously open air passageway therebetween;

continuously filling one of the said tanks to a first water level in phase with the travel of said tank into the sea during a cycle of oscillatory vessel motion; and

simultaneously continuously draining the other of said tanks to a second water level in response to the filling of said one tank during the same cycle of oscillatory vessel motion by directing air forced out of said tank being filled into said other tank through said conduit means;

said step of continuously filling one of said tanks including the step of completely filling said one of said tanks in response to predetermined angular displacement of the vessel about its axis of symmetry for rapidly increasing the righting moment thereof as a function of additional angular displacement to prevent capsizing of the vessel when the tank is completely filled.

2. The method of claim 1 further including the step of pressurizing said two tanks and said conduit means with a predetermined air pressure to select said first and second water levels in said tanks during the filling and draining steps respectively.

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